EESC 4701: Igneous and Metamorphic Petrology

IGNEOUS MINERALS

LAB 1 HANDOUT

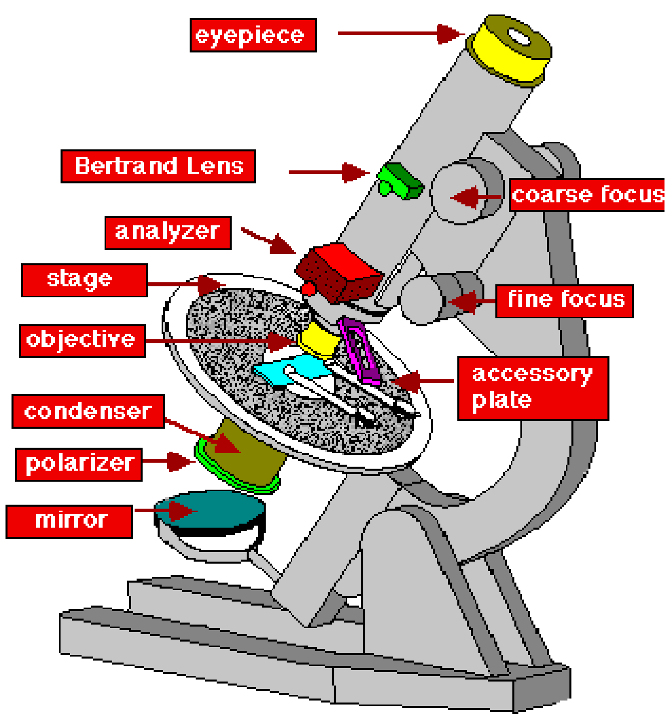
Sources: Cornell EAS302 lab, UMass Lowell 89.301 Mineralogy, LHRIC.org

The Petrographic Microscope

As you know, light is an electromagnetic wave; we can think of it as a vibrating electromagnetic field. In general, the vibration can be in any direction (up-down, side-to-side, etc). Some materials, and many minerals in particular transmit only that part of light that is vibrating in particular directions. Furthermore, the speed at which light is transmitted through a mineral depends on its vibration direction relative to the alignment of atoms in the crystal (i.e., relative to crystallographic orientation). This leads to a number of interesting optical properties than help us distinguish minerals.

Today's exercise will make use of the petrographic microscope. This microscope is designed to take advantage of the optical properties of minerals. A petrographic microscope projects light through a polarizing filter up through a glass slide containing a slice of rock cut very thin, called a thin section. A second polarizer (called the *analyzer*), whose direction of polarization is 90° to the first, can be inserted between the thin section and the eye piece. If there is nothing between the two polarizers, no light is transmitted: the field of view will appear black. This is because the first polarizer eliminates all light except for that vibrating in one direction and the second polarizer eliminates the remaining light. The stage on the petrographic microscope can be rotated, allowing you to change the optical orientation of the mineral in view.

Anatomy of a Petrographic Microscope



Elements of a thin section sketch

- Scale bar
- Magnification (*ocular* and *objective*), type of light (i.e. **PPL** or **XPL**)
  - **PPL** – means the light is *Plane Polarized Light*, and only the bottom polarizer is engaged
  - **XPL** – means the light is *Cross Polarized Light*, and both the bottom polarizer and the top polarizer (or the *analyzer*) are engaged
- Accurate sketch of color and morphology
- Small map of thin section indicating location of sketch
- Arrows and labels

Optical properties of Minerals

Most minerals can have the effect of rotating the direction of polarization of light passing through them. Thus when such a mineral is present between the polarizers, some light may still be transmitted, because its direction of vibration is no longer perpendicular to the second polarizer. Amorphous substances, such as glass, as well as “isotropic” minerals, do not have this property and will appear black when viewed with crossed polarizers. Non-isotropic minerals will also appear black where properly oriented. When they do, they are said to go to “extinction”. You will notice this when you rotate the stage with polarizers crossed.

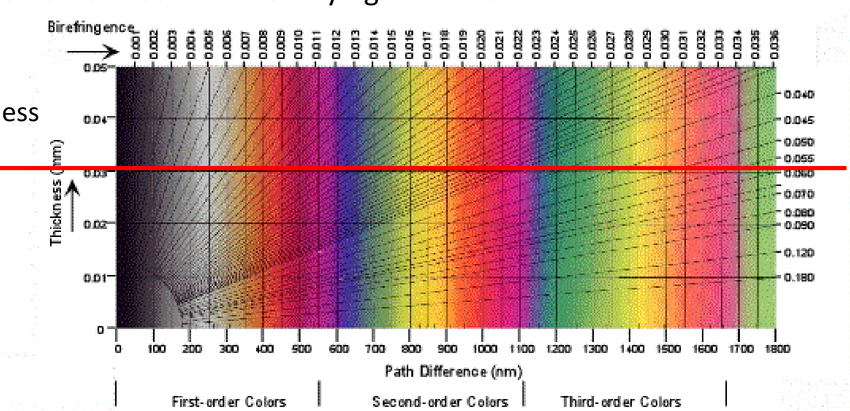
<u>Opacity</u>

Some minerals, oxides and sulfides in particular, do not transmit light at all and hence appear black, or opaque, even with the top polarizer removed. In the rocks we will view, most will be oxides of iron and titanium.

<u>Interference Colors</u>

Non-isotropic minerals will appear colored when the polarizers are crossed. These colors are not the natural ones, but rather interference colors. The result from the fact that the speed of light transmitted through the mineral depends on its vibration direction. Hence light transmitted in vibrating in plane A will travel slower and arrive at your eye than light vibrating in direction B. The light your eye detects is the sum of these two waves. This summed wave will have a frequency of vibration that depends on the difference in travel time. Your eye interprets the frequency of vibration as color. This interference color is also useful in identifying minerals.

Common thickness of thin section



Relief

If the refractive index (actually, the speed at which light is transmitted through the substance) of a substance is similar to that of air, its surface is difficult to see and it will almost seem to disappear under the microscope with the top polarizer removed. On the other hand, if the refractive index is much different than air, the surface is easy to see. In this case, the mineral is said to have relief. Quartz and feldspar have little relief, ferromagnesian minerals have moderate to high relief.

Color

You can see the natural color of the minerals when the top polarizer is removed. Quartz, feldspar, and calcite appear colorless in thin section. Ferromagnesian minerals have varying degrees of color, ranging from slight in olivine to strong in amphibole and biotite.

Pleochroism

With the top polarizer removed, the color of some minerals will change as the stage is rotated. This is a phenomenon known as pleochroism.

Twinning

Twinning is not strictly an optical property, but is most apparent when viewing minerals in thin sections. Twinning is a phenomenon is which the crystallographic orientation of a crystal (that is, the alignment of atoms), changes across a plane, called a twinning plane, that interior to the crystal. For example, the crystallographic orientation on one side of a twinning plane might be the mirror image of that on the other side.

Twinning is most obvious when the stage is rotated: part of the crystal will go extinct at one angle, while other parts will go extinct at another angle. Feldspar crystals are almost always twinned and can readily be identified this way. Quartz, which can otherwise appear similar to feldspar, is rarely twinned. Pyroxene is also sometimes twinned, but less often that feldspar.

Cleavage

Cleavage is the tendency of certain minerals to break along a preferential plane that is parallel to zones of weak bonding. Some minerals do not have cleavage (e.g., olivine) and break irregularly.

Optical properties of common minerals

The following summarizes some of the optical properties of common minerals and mineraloids:

- **Isotropic**
  - Glass
  - Garnet
- **Interference colors**
  - *Strong*: Calcite and ferromagnesion (meaning Fe- and Mg-rich) minerals such as olivine, pyroxene, amphibole, and mica
  - *Weak*: Feldspars and quartz
- **Opaque**
  - Sulfides
  - Oxides of iron and titanium (e.g., magnetite, hematite, and ilmenite)

- **Color**
    - Little or no color
        - Quartz, feldspar, calcite, olivine
    - Moderate to strong color
        - Pyroxene (usually light brown, sometimes greenish or purplish)
        - Amphibole (usually brown or green)
        - Biotite (brown or green)
- **Pleochroism**
    - Biotite and hornblende (amphibole) are often strongly pleochroic. Pyroxene occasionally shows weak pleochroism.
- **Cleavage**
    - Often olivine, pyroxene, and amphibole can be distinguished by examining their fractures
        - Olivine has no cleavage
        - Amphibole cleaves at 60° and 120°
        - Pyroxene cleaves at nearly right angles (87° and 93°)

Properties of minerals in hand samples (review from Solid Earth)

Crystal Habit

If the specimen shows crystal faces it may be possible to determine the crystal system (isometric, tetragonal, orthorhombic, hexagonal, monoclinic, triclinic) to which the mineral belongs and the symmetry class.

Color

Color is an obvious characteristic and may be an important property in the identification of minerals. Many minerals, however, exhibit a range in color due to slight variations in composition or impurities.

Streak

Streak is the color of the finely powdered mineral. It is produced by rubbing the mineral across an unglazed porcelain plate (streak plate).

Luster

Luster is the way a mineral reflects light from its surface. Types of luster:

I. **Metallic** - looks like a metal

II. **Nonmetallic**
   a. *Vitreous* - like glass
   b. *Adamantine* - brilliant like diamond
   c. *Resinous* - luster like resin

Hardness

The hardness of a mineral is its resistance to scratching. A harder mineral cannot be scratched by a softer mineral. In 1822 the Austrian mineralogist Mohs established a hardness scale consisting of ten common minerals. The first mineral is the softest known, the second is also soft but will scratch the first. The hardest mineral (number 10) is diamond and this mineral will scratch all the other minerals on the hardness scale. Hardness values for some common materials are: fingernail = 2.5, knife blade = 5.5, glass = 5.5.

Mohs' Scale is composed of the following minerals: 1 – talc, 2 – gypsum, 3 – calcite, 4 – fluorite, 5 – apatite, 6 – orthoclase, 7 – quartz, 8 – topaz, 9 – corundum, 10 – diamond

Cleavage

Cleavage is the tendency for a mineral to break along certain planes of weakness. Some minerals exhibit no cleavage, others break parallel to one plane, some parallel to two planes and some parallel to three or more planes. You should note the quality of the cleavage - perfect, good, fair, poor - and the angles between the cleavage planes.

Fracture

If a mineral possesses no cleavage it will break along an irregular or curved surface. Fracture surfaces can be described as uneven, splintery or conchoidal. Conchoidal fractures are characteristically curved like the surface of a shell. Glass and quartz break in this manner.

Density

The density of a substance is its mass per unit volume. Practically one can determine relative density by comparing the weight of standard size, usually a cubic centimeter, minerals. Often the density is expressed as a number which tells you how many times heavier the mineral is than an equal volume of water (this is termed specific gravity). Most minerals are 2.5 to 3 times as heavy as water, but others are much heavier. Often a mineral's density is a clue to its identity. You should be able to distinguish high density minerals from lower density minerals by heft (for any two minerals of approximately the same size, hold one in each hand and decide which feels heavier).

Taste (do not taste any mineral with a metallic luster) – **In our lab at Columbia, do not do this**

Some minerals, such as halite (table salt), have a distinctive taste. *Use caution.*

Magnetism

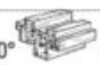
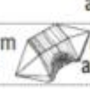
The mineral magnetite can readily be distinguished from other minerals since it is strongly attracted by a magnet.

Chemical Tests

Certain minerals react with acid. For example, when a drop of dilute acid is placed on a mineral containing carbonate (CO_3) a violent bubbling is produced. This results from the fact that CO_2 gas is produced by the chemical reaction between the mineral and the acid. This reaction proves that carbonate is present in the mineral. Two minerals, calcite ($CaCO_3$) and dolomite [$(Ca,Mg)CO_3$], which are very similar in their physical properties can be distinguished by this simple chemical test. If dilute acid is placed on dolomite a very weak, or no, bubbling occurs. If dilute acid is placed on calcite a violent bubbling is produced.

The same acid can be used to test for the presence of sulfur. Powder some of the mineral by rubbing it on an unglazed porcelain plate and then add a drop of acid. If you can detect the odor of hydrogen sulfide gas (H_2S - smells like rotten eggs) sulfur is present in the mineral.

Properties of Common Minerals

LUSTER	HARD-NESS	CLEAVAGE	FRACTURE	COMMON COLORS	DISTINGUISHING CHARACTERISTICS	USE(S)	MINERAL NAME	COMPOSITION*
Metallic Luster	1–2	✔		silver to gray	black streak, greasy feel	pencil lead, lubricants	**Graphite**	C
	2.5	✔		metallic silver	very dense (7.6 g/cm^3), gray-black streak 	ore of lead	**Galena**	PbS
	5.5–6.5		✔	black to silver	attracted by magnet, black streak	ore of iron	**Magnetite**	Fe_3O_4
	6.5		✔	brassy yellow	green-black streak, cubic crystals 	ore of sulfur	**Pyrite**	FeS_2
Either	1–6.5		✔	metallic silver or earthy red	red-brown streak	ore of iron	**Hematite**	Fe_2O_3
Nonmetallic Luster	1	✔		white to green	greasy feel	talcum powder, soapstone	**Talc**	$Mg_3Si_4O_{10}(OH)_2$
	2		✔	yellow to amber	easily melted, may smell	vulcanize rubber, sulfuric acid	**Sulfur**	S
	2	✔		white to pink or gray	easily scratched by fingernail	plaster of paris and drywall	**Gypsum** (Selenite)	$CaSO_4 \cdot 2H_2O$
	2–2.5	✔		colorless to yellow	flexible in thin sheets 	electrical insulator	**Muscovite Mica**	$KAl_3Si_3O_{10}(OH)_2$
	2.5	✔		colorless to white	cubic cleavage, salty taste 	food additive, melts ice	**Halite**	$NaCl$
	2.5–3	✔		black to dark brown	flexible in thin sheets 	electrical insulator	**Biotite Mica**	$K(Mg,Fe)_3 AlSi_3O_{10}(OH)_2$
	3	✔		colorless or variable	bubbles with acid 	cement, polarizing prisms	**Calcite**	$CaCO_3$
	3.5	✔		colorless or variable	bubbles with acid when powdered	source of magnesium	**Dolomite**	$CaMg(CO_3)_2$
	4	✔		colorless or variable	cleaves in 4 directions	hydrofluoric acid	**Fluorite**	CaF_2
	5–6	✔		black to dark green	cleaves in 2 directions at 90° 	mineral collections	**Pyroxene** (commonly Augite)	$(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$
	5.5	✔		black to dark green	cleaves at 56° and 124° 	mineral collections	**Amphiboles** (commonly Hornblende)	$CaNa(Mg,Fe)_4(Al,Fe,Ti)_3Si_6O_{22}(O,OH)_2$
	6	✔		white to pink	cleaves in 2 directions at 90°	ceramics and glass	**Potassium Feldspar** (Orthoclase)	$KAlSi_3O_8$
	6	✔		white to gray	cleaves in 2 directions, striations visible	ceramics and glass	**Plagioclase Feldspar** (Na-Ca Feldspar)	$(Na,Ca)AlSi_3O_8$
	6.5		✔	green to gray or brown	commonly light green and granular	furnace bricks and jewelry	**Olivine**	$(Fe,Mg)_2SiO_4$
	7		✔	colorless or variable	glassy luster, may form hexagonal crystals 	glass, jewelry, and electronics	**Quartz**	SiO_2
	7		✔	dark red to green	glassy luster, often seen as red grains in NYS metamorphic rocks	jewelry and abrasives	**Garnet** (commonly Almandine)	$Fe_3Al_2Si_3O_{12}$